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AZUSA PLANT

STRUCTURAL MATERIALS DIVISION

INVESTIGATION OF STRESS-CORROSION CRACKING OF HIGH-STRENGTH ALLOYS

A Report To

FRANKFORD ARSENAL

Contract DA-04-495-ORD-3069

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AEROJET GENERAL TIRE GENERAL

AEROJET-GENERAL CORPORATION

This is the twenty-fourth in a series of informal monthly progress reports submitted in partial fulfillment of Contract DA-04-495-ORD-3069. It constitutes the eighth monthly progress report for the one-year continuation of the original two-year program.

This report covers the period 1 May through 31 May 1963. It was written by R. B. Setterlund, who was supervised by A. Rubin.

AEROJET-GENERAL CORPORATION

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NOTE: The information contained herein is regarded as preliminary and subject to further checking, verification, and analysis.

I. OBJECTIVES

The objectives of this program are outlined below:

A. Investigation of the stress-corrosion cracking characteristics of at least three new high-strength alloys of interest for rocket motor-case applications. These alloys are 6Al-4V titanium, 18%-nickel maraging steel, and 20%-nickel maraging steel, in addition to limited testing of vacuum-melted 9Ni-4Co steel.

B. Study of the environmental parameters that could affect the rate and extent of stress-corrosion cracking.

C. Determination of the effect of material parameters (composition, strength level, welding, and microstructure) on stress-corrosion susceptibility.

D. Continuation of the evaluation of protective coatings and other techniques for preventing stress-corrosion cracking.

II. SUMMARY

Testing has been started on the final remaining alloy of the program - a vacuum-cast 9%-nickel 4%-cobalt steel with approximately 0.30% carbon. This alloy has shown some failures in the 140°F water-saturated air environment.

III. WORK PROGRESS

A. INTRODUCTION

Since the initiation of the original test program two years ago to investigate the stress-corrosion cracking characteristics of high-strength alloys, a number of new high-strength steels have been receiving increased attention for use in constructing rocket-motor cases. The third-year test program is directed to the study of three of these new alloys, as well as of one titanium alloy presently being used for the same application.

The test environments, substantially the same as those evaluated in the original two-year investigation, are as follows: (1) distilled water; (2) tap water; (3) salt water; (4) sodium-dichromate-inhibited water; (5) soluble oil-inhibited water; (6) air; (7) high-humidity atmosphere; (8) trichloroethylene; and (9) cosmoline. These are considered to be environments representative of those to which the cases would normally be exposed during fabrication, processing, and storage. One additional environment is included in the new program, that of sea-coast atmospheric exposure.

The test methods being used in this investigation employ bent-beam, U-bend, and center-notched specimens. Evaluation of results included micro-structural studies, using both standard metallographic and electron microscopic techniques, to attempt to associate the failure mechanism with specific micro-structural characteristics of the materials.

An evaluation of protective coatings and surface treatments to prevent stress-corrosion cracking is also being conducted.

The scope of the program is shown in Table 1.

B. WORK PROGRESS

During the period covered by this report, four groups of specimens of vacuum-cast 9%-nickel 4%-cobalt steel were placed in test. The material was tested at three strength levels attained by double-tempering at 400, 600 and 800°F. Material at each strength level was exposed to four environments: aerated distilled water, aerated tap water, aerated salt water, and 140°F water-saturated air. The chemical and physical properties of the material is shown in Table 2. Results to date, Table 3, show that the only failures have occurred in the 140°F water-saturated air environment.

IV. FUTURE WORK

Work is continuing along the guidelines of the master plan (Table 1). Both bent-beam and center-notched specimens are being tested to fulfill as much as possible of this schedule.

Metallographic sections of selected cracked samples have been photographed and presented in the last quarterly report. In addition, photomicrographs will be made of welded 18 and 20%-nickel steel samples which have failed in test.

Three samples were studied by means of the electron microscope, utilizing fracture replicas. Selected fractographs were presented in the last quarterly report. For the final report an additional set of fractographs is being prepared, using a failed sample of annealed and aged 18%-nickel maraging steel.

V. BUDGET

The expenditure rate for the month of May was 46 hours, leaving a balance of 160 hours for the remainder of the contract period.

Alloy	Processing Condition (Titanium Content of Maraging Steel Shown)	Strength Level, 0.2% Offset Yield (psi)	Specimen Code	Distilled Water	Tap Water	3% NaCl Solution	0.25% Sodium Dichromate Solution	4% Soluble Oil Solution	High Humidity	Trichloro-ethylene	Cosmoline	Solid Propellant	Ambient Air	Sea Coast Atmosphere	Total
				Number of Test Environments											
6Al-4V titanium	Annealed	138,000	G-1	3*	3	3	3	3	3	3	3	3	-	3	30
	Quenched and Aged	163,000	G-2	3	3	3	3	3	3	3	3	3	-	3	30
	Welded	135,000	G-W	2	2	2	2	2	2	2	2	-	2	2	20
	Total			8	8	8	8	8	8	8	8	6	2	8	80
20%-Nickel Maraging Steel	Annealed and Aged	291,000	H-1	3	3	3	3	3	3	3	3	3	3	3	33
	50% CW and Aged	321,000	H-2	3	3	3	3	3	3	3	3	3	3	3	33
	75% CW and Aged	298,300	H-3	3	3	3	3	3	3	3	3	3	3	3	33
	Welded and Aged	To be tested	H-W	3	3	3	3	3	3	3	3	3	3	3	33
	Total			12	12	12	12	12	12	12	12	12	12	12	132
18%-Nickel Maraging Steel	Annealed & Aged (0.62% Ti)	283,000	I-1	3	3	3	3	3	3	3	3	3	3	3	33
	50% CW & Aged (0.50% Ti)	302,400	I-2	3	3	3	3	3	3	3	3	3	3	3	33
	50% CW & Aged (0.62% Ti)	323,000	I-3	3	3	3	3	3	3	3	3	3	3	3	33
	Annealed & Aged (0.50% Ti)	249,900	I-4	3	3	3	3	3	3	3	3	3	3	3	33
	50% CW & Aged (0.40% Ti)	278,000	I-5	3	-	2	-	-	3	-	-	-	1	2	11
	Annealed & Aged (0.52% Ti)	255,400	I-6	3	-	2	-	-	3	-	-	-	2	3	13
	50% CW & Aged (0.52% Ti)	331,000	I-7	3	-	2	-	-	3	-	-	-	2	3	13
	Annealed & Aged (1.00% Ti)	323,200	I-8	3	-	2	-	-	3	-	-	-	1	2	11
	50% CW & Aged (1.00% Ti)	354,400	I-9	3	-	2	-	-	3	-	-	-	2	2	12
	Welded & Aged (0.50% Ti)	To be tested	I-W	3	3	3	3	3	3	3	3	3	3	3	33
	Total			30	15	23	15	15	30	15	15	15	23	27	225
9 Ni-4 Co Vacuum-Cast Alloy	Aged (0.25-0.30% C)	To be tested	J-1	3	3	3	3	3	3	3	3	3	3	3	33
	Aged (0.40-0.45% C)	To be tested	J-2	3	3	3	3	3	3	3	3	3	3	3	33
	Total			6	6	6	6	6	6	6	6	6	6	6	66
H-11 Steel (Coating Tests)	Application of Various Protective Coatings			-	-	37	-	-	29	-	-	-	-	26	92
	Total			56	41	86	41	41	85	41	41	39	43	79	595

*Number of replicate tests conducted.

Master Plan - Bent-Beam Stress-Corrosion Tests

Table 1

TABLE 2

CHEMICAL ANALYSIS AND MECHANICAL PROPERTIES OF 9Ni-4Co VACUUM CAST ALLOY

Mill Certified Chemical Analysis*

C	Mn	P	S	Si	Co	Ni	Cr	Mo	V
0.30	0.23	0.006	0.007	0.02	4.10	8.65	0.43	0.35	0.10

Mechanical Properties (Transverse) Aerojet Tests

Condition	Yield Strength (0.2% Offset) ksi	Ultimate Tensile Strength ksi	Elongation %	% Reduction of Area	Rc Hardness
(Austenitized 1550°F in argon - oil quenched 2 hours double temper at temperatures shown)					
400°F	190.3	230.3	8	52	48
600°F	184.6	203.0	7	54	43
800°F	172.4	186.7	9	59	41
1000°F	176.7	187.1	11	60	40.5

*Republic Heat 3950924.

TABLE 3

BENT-BEAM TESTS, STRESS CORROSION OF 9Ni-4Co STEEL*

Environment	Tempering Temperature (°F)	Failure Ratio**	Failure Time (hr) Mean	Failure Time (hr) Range
140°F Saturated Air	400	3/3	187	115-260
	600	1/3	428	428-NF500
	800	0/2	-	NF 170**
Aerated Distilled Water	400	0/3	-	NF 500
	600	0/3	-	NF 500
	800	0/2	-	NF 170
Aerated Tap Water	400	0/3	-	NF 500
	600	0/3	-	NF 500
	800	0/2	-	NF 170
Aerated Salt Water	400	0/3	-	NF 500
	600	0/3	-	NF 500
	800	0/2	-	NF 170

*All samples austenitized at 1550°F, oil-quenched and double-tempered at indicated temperatures for 2 hours. All samples were stressed to give a maximum outer-fiber stress of 75% of the 0.2% offset yield strength.

**Failure ratio is the number of specimens failed over the number of specimens tested. NF indicates no failures were obtained.